Allowing for Group Effects When Estimating Import Demand for Source and Product Differentiated Goods

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Abstract: In this study an import demand model (differential production model) is presented that is used in estimating the demand for source and product differentiated goods simultaneously. Unlike the traditional import demand models, this model can account for changes in relative group expenditures. Expenditure estimates differed when comparing the differential production model and Rotterdam model results. Results showed that if group revenue shares are relatively fixed, then the bias in expenditure estimates due to omitting group effects will be small when using traditional demand models such as the AIDS or Rotterdam models. As relative group shares significantly change and diverge the bias increases, particularly for imports representing a larger share of group expenditures.

Keywords: Import demand, AIDS model, Rotterdam model, product differentiation, source differentiation

JEL classification Number: F17, Q17, Q11.

1. Introduction

Demand studies have either focused on related products (e.g. beer, wine, and spirits) or a single product from different sources (e.g. French wine, Italian wine, New Zealand wine). However, more recent applications have considered demand for related product groups with source differentiation within each group. Recent studies include: Molina, 1997; Carew, Florkowski, and He 2004; Henneberry and Hwang 2007; Muhammad, Keithly and Hann, 2007. These studies investigated cross-country relationships for a given product, cross product relationships for a given country, and cross product/cross country relationships (e.g. German cars versus U.S.

trucks) simultaneously using traditional import demand models (Almost Ideal Demand System, Rotterdam, etc.).

In each of the mentioned studies, a country's demand for a given product was a function of total expenditures (on all groups) and individual import prices. A problem with using a traditional demand specification in this context is that the demand for individual imports is impacted by total expenditures only and the impact of relative group expenditures is overlooked. There are three possible stages to consider when estimating import demand for related product groups: (1) the determination of total expenditures, (2) the allocation of total expenditures across each product group, and (3) the allocation of group expenditures across import suppliers. Consider an extreme case where expenditures on one group are equally replaced with expenditures on another such that total expenditures remain constant. While it is clear that individual imports within each group should also change, if one considers total expenditures only, then individual imports (predicted value) in the model would remain unchanged because total expenditures did not change.

Single expenditure demand specifications are acceptable if importing firms are input-output separable, that is if relative group expenditures are independent of within-group allocations. Or more simply stated, a dollar increase in total imports has the same effect on an individual import regardless to the product group the dollar is spent. This is highly unlikely given that individual goods are often unique to product groups. However, it is possible for group expenditures to change proportionally, that is a dollar increase in total imports is always divided among groups at relatively the same share. If this is the case, relative group shares will be fixed making groups effects of no consequence. If neither condition holds, then a single-expenditure demand specification may lead to bias expenditure estimates. In this study a demand model is presented that estimates import demand for goods differentiated by product group and country of origin and accounts for the impact of relative group effects. The demand model presented is derived from production theory where import demand is consider as derived demand and allows for testing the input-output separability condition (or fixed group-shares restriction).

2. Theoretical and Empirical Model

The conditional import demand model for related product groups with source differentiated within each group is derived from the differential approach to the multiproduct firm (Theil, 1980; Laitinen, 1980). Assume a firm that imports *n* goods belonging to *m* product groups where each product group contains a subset of *n*. For example, if the United States imports cars from 4 sources and trucks from 3 sources, then *n* is equal to seven and *m* is equal to two, and the group "trucks" contains 3 good and the group "cars" contains 4 goods. Let p_r and q_r represent the domestic price (weighted average resale price) and import volume for product group r $(r, s \in m)$, and w_i and x_i represent the price and quantity of imported good i $(i, j \in n)$. According to Laitinen (1980, p. 90) a conditional demand system for a cost minimizing firm (in matrix notation) is specified as

$$\mathbf{F}d(\log \mathbf{x}) = \gamma \mathbf{KG}d(\log \mathbf{q}) - \psi\left(\mathbf{\Theta} - \mathbf{\theta\theta}'\right) d(\log \mathbf{w}) . \qquad (1)$$

Note that the vector **q** contains group quantities, and the vectors **x** and **w** contain individual import quantities and prices respectively.

$\mathbf{F}_{n\times n}$ is a diagonal matrix with import cost shares $\left(f_i = w_i x_i \big/ \sum_i w_i x_i \right)$ along the diagonal.

$\mathbf{K}_{n\times m}$ is a matrix which has θ_i^r as the (*i*,*r*)th element where $\theta_i^r = \dfrac{\partial(w_i x_i)}{\partial(p_r q_r)}$ and is the additional expense on the *i*th import incurred from a dollar increase in product group *r*.

$\mathbf{G}_{m\times m}$ is a diagonal matrix with group value shares $\left(g_r = p_r q_r \big/ \sum_r p_r q_r\right)$ along the diagonal.

$\mathbf{\Theta}_{n\times n}$ is a symmetric positive definite matrix where $\mathbf{\Theta} = \dfrac{1}{\psi}\mathbf{F}(\mathbf{F}-\gamma\mathbf{H})^{-1}\mathbf{F}$. $\mathbf{H}$ is the Hessian matrix of the firm's implicit production function, where the elements of $\mathbf{H}$ are the second partials with respect to inputs $\left(\partial h^2 \big/ \partial\mathbf{x}\partial\mathbf{x}'\right)$. $\boldsymbol{\theta} = \mathbf{\Theta}\boldsymbol{\iota}$ and $\boldsymbol{\iota}'\boldsymbol{\theta} = 1$.

γ is the revenue cost ratio, $\gamma = \dfrac{\sum_r p_r q_r}{\sum_i w_i x_i}$.

ψ is a positive scalar where $\psi = \boldsymbol{\iota}'\mathbf{F}(\mathbf{F}-\gamma\mathbf{H})^{-1}\mathbf{F}\boldsymbol{\iota}$ and may be regarded as a measure of the curvature of the logarithmic cost function.

From equation (1) a Rotterdam-type conditional import demand system (expressed in finite log changes) is expressed as (Laitinen, 1980)

$$\bar{f}_{it} Dx_{it} = \sum_{r=1}^{m} \theta_i^r \bar{q}_{rt} + \sum_{j=1}^{n} \pi_{ij} Dw_{jt} + \varepsilon_{it} . \tag{2}$$

D is the log change operator where for any variable *z*, $Dz_t = \log(z_t / z_{t-1})$. $\bar{q}_{rt} = \bar{\gamma}_t \bar{g}_{rt} Dq_{rt}$, where $\bar{\gamma}_t = (\gamma_t \gamma_{t-1})^{1/2}$ and $\bar{g}_{rt} = (g_{rt} + g_{rt-1})/2$. $\bar{f}_{it} = (f_{it} + f_{it-1})/2$; θ_i^r is as previously defined; and π_{ij} is the conditional price effect which measures the impact of the price of import *j* on the demand for import *i*. $\mathbf{\Pi} = \left[\pi_{ij}\right] = -\psi\left(\mathbf{\Theta} - \boldsymbol{\theta}\boldsymbol{\theta}'\right)$. θ_i^r and π_{ij} are parameters to be estimated and are assumed constant. ε_{it} is a random disturbance term, normally distributed with zero mean and constant variance.

The above model requires that the following parameter restrictions be met in order to conform to theoretical considerations: $\sum_i \theta_i^r = 1$ and $\sum_i \pi_{ij} = 0$ (adding up), $\sum_j \pi_{ij} = 0$

(homogeneity), and $\pi_{ij} = \pi_{ji}$ (symmetry). Additionally, the matrix of import price effects should be negative semi-definite $\sum_i \pi_{ii} \leq 0$.

Input-output separability implies that $\theta_i^r = \theta_i^s = \theta_i$. With this restriction equation (2) is restated as

$$\bar{f}_{it} Dx_{it} = \theta_i DX_t + \sum_{j=1}^{n} \pi_{ij} Dw_{ij} + \varepsilon_{it} . \tag{3}$$

DX_t is the finite version of the Divisia index, a measure of change in total import expenditures, where $DX_t = \sum_{i=1}^{n} \bar{f}_{it} Dx_{it} = \theta_i \sum_{r=1}^{m} \bar{q}_{rt}$. Note that equation (3) is the Rotterdam model, a specification that is commonly used in import demand analysis. Therefore, a test for the appropriateness of equation (3) is to test the input-out separability restriction in equation (2). While this condition suggests that total expenditures matter and not group expenditures, it is also possible to test the condition that group expenditures matter and not total expenditures. This would be the case if $\theta_i^r = 0$ for all *i* not belonging to product group *r*.

3. Empirical Results

Import demand for fresh cut flowers in the EU was estimated as an empirical illustration. Analysis was limited to two groups: roses and other cut flowers. Individual imports included: Ecuador (roses), Kenya (roses), ROW (roses), Israel (other), Kenya (other), and ROW (other). The External trade section of the Statistical Office of the European Communities (Eurostat) provided the data used in this study. Imports were at the CN8 commodity classification level. Quantities were in 100 kilograms (kg) and values were in euros. Import values included cost, insurance and freight (CIF). Monthly data was used for estimation, and the time period for the data was from January 2000 through December 2006. Per-unit values were used as proxies for import prices (€ per 100 kg). ROW quantities and values were calculated as the difference between total imports and imports from top suppliers. As a proxy for domestic price, per-unit export values were used since imports were often re-exported. Exports were on a free-on-board (FOB) basis.

The conditional import demand system was estimated using the LSQ procedure in TSP version 5.0. This procedure uses the multivariate Gauss-Newton method to estimate the parameters in the system (Hall and Cummins, 2005). Given the singularity of the system (due to the adding up property), the ROW equation was dropped for estimation. To account for seasonality, equation (2) was estimated with monthly dummy variables. Likelihood ratio (LR) tests were used to test for AR(1) disturbances using the maximum likelihood procedure for singular systems found in Beach and MacKinnon (1979). LR tests were also used to test the economic conditions of homogeneity and symmetry. LR tests rejected AR(1), and failed to reject homogeneity and symmetry at the 0.05 significance level. Test results rejected group effect extremes, $\theta_i^r = \theta_i^s = \theta_i$ and $\theta_i^r = 0$. Log likelihood values, LR test statistics and P-values are given in Table 1.

Conditional demand estimates are presented in Table 2. Overall, the model performed well. All own-price effects were negative which implied that the conditional price-effect matrix was negative semidefinite, most were significant at the 0.5 level. Cross-country competition was found for Ecuador and ROW roses, Israel and ROW other, and Kenya and ROW other. Kenya is the only country with exports of both products; however, no cross-product competition existed for the country. There was only one instance of cross product/cross country competition, ROW roses and Israel other.

Table 1. LR Tests for Homogeneity, Symmetry and Group-Effect Conditions

Model (Conditions)	Log-likelihood Value	LR Statistic [a] $\chi^2_{(j)}$	P-value	
Unrestricted Model	1279.97			
Homogeneity	1279.13	1.68(6)	0.95	Fail to Reject
Symmetry	1267.67	22.91(15)	0.09	Fail to Reject
$\theta_i^r = \theta_i^s\ \forall r$ and s	1192.72	149.91(6)	0.00	Reject
$\theta_i^r = 0 \forall i \not\subset r$	1192.63	150.08(6)	0.00	Reject

[a] The number of restricted parameters is in parenthesis.

Own-group effects were significantly larger than cross-group effects for each import, the only exception being ROW roses (0.30 and 0.27). For Kenya, not only were own-group effects larger, but cross-group effects were insignificant. Results show that group effects matter and should be considered when estimating import demand for multiple product groups. Although the group-expenditure independence condition $(\theta_i^r = 0)$ was rejected, statistically this was actually the case for Kenya.

Total expenditure effects θ_i can be derived from individual group effects as follows, $\sum_r \bar{g}_r \theta_i^r = \theta_i$ (Laitinen, 1980). Table 3 compares total expenditure estimates derived from equation (2) and equation (3). Results show that Rotterdam estimates tended to underestimate expenditure effects for the dominant group (roses: revenue share = .61) and overestimate expenditure effects for the less dominant group (other: revenue share = .39). Although expenditure estimates differed between models, the difference was statistically small suggesting that using the Rotterdam model for this application would not have resulted in biased expenditure estimates. This is likely due to group revenue shares being relatively fixed at 60 percent for roses and 40 percent for other throughout most of the data period. When revenue shares diverged (See 2006 in Table 4), the difference in estimates between models became larger and significant for Kenyan roses, the largest rose group, and Israeli other, the largest other group. This suggests that the bias associated with using traditional demand models will depend on the difference in group revenue shares and the degree to which revenue shares change throughout the data period.

Table 2. Conditional Import Demand Estimates for Cut Flowers in the EU

	Price Coefficients π_{ij}						Group Effects θ_i^r	
Exporting Country	Roses			Other				
	Ecuador	Kenya	ROW	Israel	Kenya	ROW	Roses	Other
Roses								
Ecuador	-0.057** (.009)	0.025 (.014)	0.024* (.011)	0.004 (.007)	0.003 (.008)	0.001 (.006)	0.113** (.017)	0.058** (.020)
Kenya		-0.019 (.041)	0.012 (.030)	-0.022 (.016)	0.007 (.020)	-0.001 (.014)	0.389** (.027)	-0.035 (.043)
ROW			-0.053* (.027)	0.031* (.014)	-0.017 (.015)	0.002 (.012)	0.296** (.031)	0.267** (.038)
Other								
Israel				-0.047** (.013)	0.007 (.008)	0.027** (.009)	0.080** (.026)	0.399** (.032)
Kenya					-0.007 (.011)	0.027** (.011)	0.019 (.024)	0.107** (.029)
ROW						-0.035** (.010)	0.104** (.020)	0.203** (.025)
Equation R^2	.95	.96	.96	.96	.84	.97		
Factor Share (f_i)	0.09	0.30	0.21	0.15	0.09	.15		
Revenue Share (g_r)	Roses = 0.61			Other = 0.39				

Notes: Asymptotic standard errors are in parentheses.
** Significance level = .01; * Significance level = .05;

Table 3. Total Expenditure Estimates and Difference between Models

	Roses			Other		
θ_i	Ecuador	Kenya	ROW	Israel	Kenya	ROW
Production Model	0.092** (.010)	0.224** (.021)	0.285** (.018)	0.204** (.015)	0.053** (.014)	0.143** (.012)
Rotterdam Model	0.089** (.010)	0.205** (.025)	0.283** (.018)	0.218** (.019)	0.057** (.014)	0.147** (.012)
Difference	0.002	0.019	0.001	-0.014	-0.004	-0.004

Table 4. Difference in Expenditure Estimates Between Models Overtime

	Revenue Share		Roses			Other		
Year	Roses	Other	Ecuador	Kenya	ROW	Israel	Kenya	ROW
2000	.59	.41	0.001	0.010	0.001	-0.008	-0.002	-0.002
2001	.61	.39	0.002	0.019	0.001	-0.014	-0.004	-0.004
2002	.60	.40	0.002	0.014	0.001	-0.011	-0.003	-0.003
2003	.60	.40	0.002	0.014	0.001	-0.011	-0.003	-0.003
2004	.58	.42	0.001	0.006	0.000	-0.005	-0.001	-0.001
2005	.64	.36	0.004	0.029	0.002	-0.022	-0.006	-0.007
2006	.67	.33	0.005	**0.043**	0.003	**-0.032**	-0.009	-0.010

Bold indicates significance level ≤ 0.10.
Difference = Production model estimate - Rotterdam model estimate.

4. Summary and Conclusion

This study presented an alternative model when estimating demand for imported goods differentiated by product group and country of origin. Traditional models are acceptable if importing firms are input-output separable or if group expenditure shares are relatively fixed; however, the results of this study rejected input-output separability suggesting that traditional specifications would likely produce bias estimates. Although expenditure estimates differed when comparing the production model to the Rotterdam model, the bias in estimates was significantly small. Overall, results showed that if group shares are relatively fixed, then the bias in expenditure estimates will be small. However, as relative group shares significantly change and diverge, then the bias increases, particularly for imports representing a larger share of group expenditures. In this study only two product groups were considered and value shares were relatively equal throughout the data period. For a greater number of products, and relatively unequal value shares, traditional models may produce more bias estimates.

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